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SIMPLE MESSAGING AND COLLABORATION SYSTEM FOR HETEROGENEOUS ORGANIZATIONS OPERATING IN DISASTER ENVIRONMENTS

by

Ramsey Meyer

September 2011

Thesis Advisor:	Alex Bordetsky
Second Reader:	Aruna Apte

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SIMPLE MESSAGING AND COLLABORATION SYSTEM FOR HETEROGENEOUS ORGANIZATIONS OPERATING IN DISASTER ENVIRONMENTS

Ramsey Meyer
Civilian, Cebrowski Institute
A.B., Occidental College, 2004

Submitted in partial fulfillment of the
requirements for the degree of

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NAVAL POSTGRADUATE SCHOOL
September 2011

Author: Ramsey Meyer

Approved by: Dr. Alex Bordetsky
Thesis Advisor

Dr. Aruna Apte
Second Reader

Dr. Daniel Boger
Chair, Department of Information Sciences

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ABSTRACT

A novel communication system for use by a wide variety of first responders in disaster response is described. The system is based primarily on SMS messaging technologies and either indigenous mobile phone service providers or mobile phone service brought in via cellular-on-wheels (COWs), UAVs, rapidly deployed towers, etc. End users use either their own cell phones, running a native SMS application, or low-cost phones that are distributed by a large non-governmental organization, such as UN OCHA. If a proprietary network is set up, SIM cards are distributed to end users to allow access to the network, or administrators will explicitly allow access via a phone’s IMEI number or other access control methods.

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LIST OF ACRONYMS AND ABBREVIATIONS

APAN	All Partners Access Network
COTS	Commercial Off-the-Shelf
COWS	Cellular-on-Wheels System
EMS	Emergency Medical Services
EOC	Emergency Operations Center
GSM	Global System for Mobile communications
HCH	Hatian Community Hospital
ICRC	International Committee of the Red Cross
IDP	Internally Displaced Persons
IMEI	International Mobile Equipment Identifier
JCSE	Joint Communication Support Element
NGOs	Non-Governmental Organizations
OSOCC	On-Site Operations Coordination Center
SIM	Subscriber Identity Module
SMS	Short Message Service
UAV	Unmanned Aerial Vehicle
USAR	Unified Search and Rescue
VoIP	Voice over Internet Protocol

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And to my family, from where my knowledge grows and my ideas originate, and from whom I derive strength, thank you.

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I. INTRODUCTION

In the late afternoon on 12 January 2010, a 7.0 magnitude earthquake struck Port-au-Prince, Haiti, instantly killing tens of thousands and entrapping hundreds of thousands under the remnants of poorly constructed dwellings, offices, shops, and other structures (*The Economist* 2010, 35–36). Public infrastructure and utilities, such as roads, electricity, water, and communications networks were severely degraded. Already home to a United Nations peacekeeping mission before the earthquake, Haiti's extant capacity to care for its residents was minimal, let alone to respond to a natural disaster of such magnitude. With a population of 1.2 million, it was clear that Port-au-Prince needed help.

The international community responded almost immediately with offers of financial and material assistance. Foreign governments and non-governmental organizations (NGOs) alike mobilized food distribution, medical care, Unified Search and Rescue (USAR) teams, and other vital services. As new information of the severity of the earthquake spread, the size of the response slowly built until a tidal wave of support flowed into Haiti.

This surge of aid did not include large-scale assistance with communication technology, a vital and oft-forgotten service. Even some of the largest NGOs did not have a reliable method for team members to communicate with other organizations; most relied on temporally-asymmetric and Internet-access reliant e-mail to conduct business, which meant the lack of widespread Internet access significantly slowed relief operations. Without a unified communication platform the relief effort was severely hindered, slowing first responders' ability to relay crucial information.

The lack of communication technology also contributed to an overall lack of interorganizational cooperation. Collaboration has the potential to create new communities that in turn build personal relationships and increase morale among first responders (Meier and Munro 2010, 91–103). By coordinating and pooling relief efforts, all first responders combined create great synergies that can—and do—result in saved lives (Comfort and Kapucu 2006, 309–327).

If a physical space were created where representatives of each organization could always be found, and a virtual commons were created where all other first responders could be contacted, the difficult communication situation, both physical and social, could be greatly improved.

This novel conglomeration of first responders represents an enterprise of sorts, an ad-hoc group of responders working in the same virtual as well as physical space, with the similar macroscopic goals.

Due to a lack of physical infrastructure and enterprise architecture to promote cross-organizational cooperation, a variety of communication gaps were apparent in post-earthquake Port-au-Prince. Inspired by these observed shortfalls, this paper proposes a novel physical and social communication system based on tested and reliable standardized technologies. Utilizing cheap mobile phones, a Global System for Mobile Communications (GSM) network, open source software, and a physical Emergency Operations Center (EOC) space that all first responder organizations would be compelled to use, this paper does not propose inventing any new technologies. Instead, this study offers new ways to use the best of what already exists, and in so doing, improve cross organizational communication between implementing partners while minimizing the cost to create the system.

What follows is a description of the disaster relief problem space as it exists today, the physical space in which relief workers operate, a description of the proposed communication system and associated enterprise architecture, and suggestions for ways that first responders could discover and use the system. This is not a detailed technical discussion, nor is it intended as a policy paper. The ultimate hope is that the suggestions in this study can be used as a nidus point from which to develop and grow an easy-to-use, universal communication system available to all disaster response organizations that they may use to interact more efficiently, and in so doing, help to alleviate human suffering.

A. LITERATURE REVIEW

Many have attempted to design first responder communication systems for disaster areas. Aldunate, Ochoa, et. al designed a novel communication and routing system based on a novel short range wireless technology, and tested the system with firefighters and civil engineers (Aldunate et al. 2006, 13–27). Mehendale, Paranjpe, et. al created an ad hoc routing protocol for WiFi networks that allows devices loaded with specialized software to participate in a network without centralized infrastructure or a “master” node (Mehendale, Paranjpe, and Vempala 2011, 446–447). Smart, Alistair-Russell, et. al described a situational awareness system they dubbed AKTiveSA, which consists of several visualization software packages, communication aggregators, and information filters designed to help first responders—primarily military first responders—gain a better understanding of the disaster area (Smart et al. 2007, 703–716). Gaber proposed a system that would utilize smartphones and high bandwidth connections to show first responders a customized screen that showed only the information that is relevant to that particular responder (“Disasters Unfold” n.d.).

Similarly, many have written about characteristics of successful disaster response information systems. Bui, Sankaran, et. al designed a framework for “global information networks” for use in disaster areas, and outlined some recommendations for the social interactions required by collaborative environments where participants are mixed from groups with different goals and priorities (Bui et al. 2000, 427–442). Daly suggested that an unclassified, open-to-all network is vitally important to decreasing cross-organizational friction and increasing efficiency and effectiveness of HA/DR operations (Daly 2007). Gomez and Turoff proved that SMS (Short Message Service) text is an effective technology to use in disaster relief operations, and that since many users are already familiar with using SMS in their everyday lives, it can be expected that virtually any first responder in any part of the world would be able to operate an SMS-centric system (Gomez and Turoff 2007, 45–50). Meier and Munro documented the successes of a crowdsourced SMS system used by victims in Haiti to report both emergencies and non-emergencies to first responders (Meier and Munro 2010, 91–103). Summer used the earthquake in Haiti as a case study and outlined the lack of communication technology available in disaster areas, and described how NGOs very rarely bring their own ICT (Summer 2010, 55–68). In their detailed essay *Disaster Relief 2.0: The Future of Information Sharing in Humanitarian Emergencies*, The United Nations Foundation et. al showed how communication and information sharing technologies are vital to the successful conduct of a disaster relief mission, and how the emergence of mobile technologies paired with crowdsourcing has become an extremely powerful combination (United Nations Foundation et al. 2011).

All of these previous works share two common threads. First, they all acknowledge the value of communication technologies in disaster response and advocate more widespread cooperation between different organizations in order to realize greater efficiencies and effectiveness. Second, all of the works that propose systems either stop short of proposing a tangible solution and an organizational construct under which to operate the system. Some papers put forward overwrought and proprietary network technologies that would be difficult to implement in the best of environmental conditions, and virtually impossible to implement in the austere environments found in disaster areas.

The system proposed in this thesis will utilize SMS, one of the most widely used, cheapest, familiar, resilient, and lowest bandwidth technologies available. All of the hardware and software required for the system already exists as commercial off-the-shelf technology. In addition, the social framework under which the system would be used is easy to understand, and is consistent with current disaster area practice. These factors all combine to form a novel approach to disaster communications, both social and physical. (See Figure 1.)

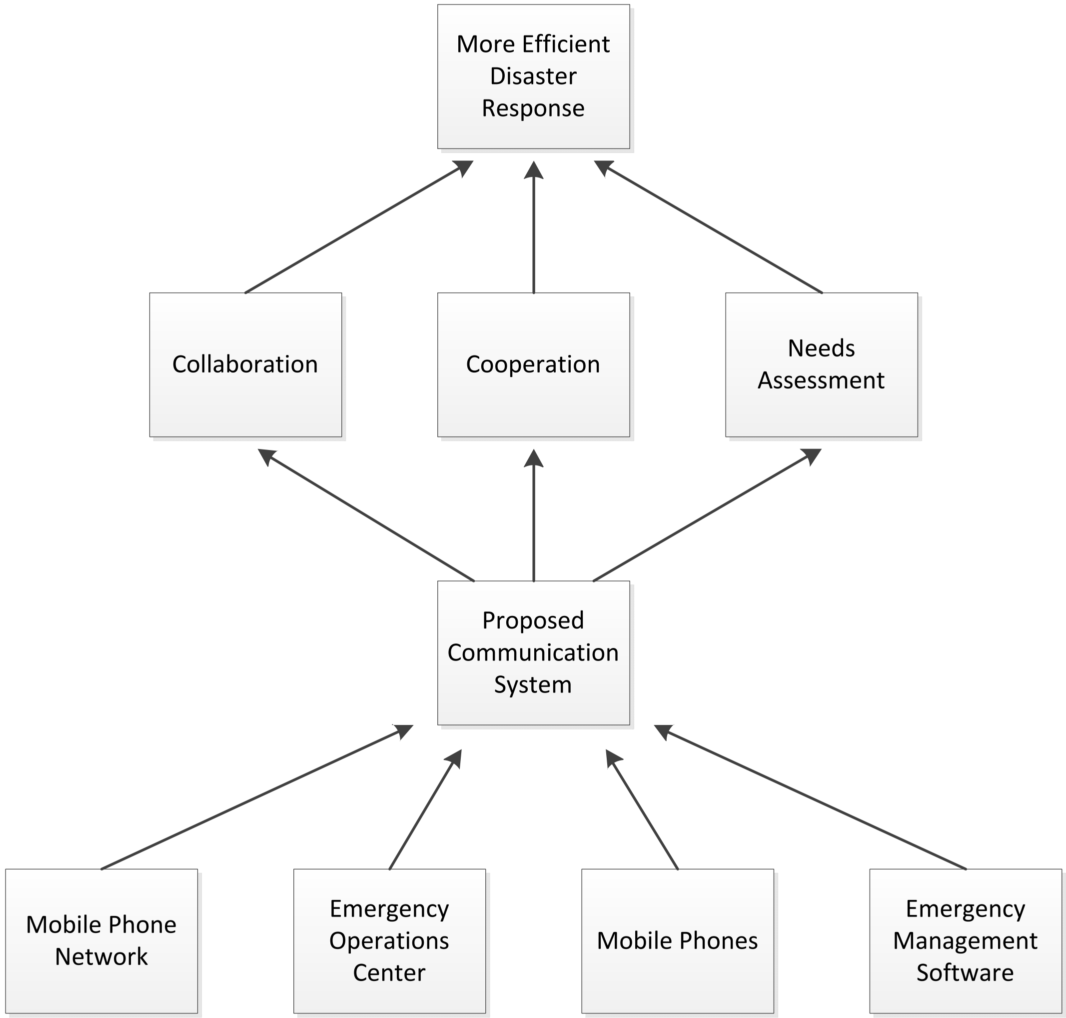

Figure 1. Component Inputs of the Proposed System and Desired Outputs.

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II. PROBLEM SPACE

The austere conditions found in disaster areas present a unique challenge to first responders and victims who attempt to communicate, operate, and survive within that space. Vital utilities and infrastructure are often either severely degraded or completely destroyed. Electrical power is often non-existent, telephone lines do not work, cell phones are inoperable, and wireless backhaul connections to distant areas are often knocked offline. Depending on the type of disaster, physical structures such as apartment buildings, businesses, hospitals, and homes may be unsafe for human habitation. Earthquake can cause structural instability; storm surges from tsunami or hurricanes can create unsanitary conditions as waste products from sewage treatment plants, landfills, chemical plants, etc., is blasted through city streets and into buildings. Surges of water also mean that any electrical equipment that is low enough to the ground—within the first floor of a building, for example—will likely be filled with brackish water, rendering the equipment inoperable immediately following the disaster, and in most cases will need to be completely replaced in order to restore communication networks.

Even the systems that should be the most reliable are often knocked offline, such as the voice radio networks used by police, fire, emergency medical services (EMS). Those systems are reliant upon terrestrial radio repeaters that are vulnerable to sundry disasters, and when they are online, the radio systems of different agencies are often not interoperable, meaning cross-organizational communication is difficult. Communication across groups can often only be accomplished over more device and network agnostic methods, such as telephone or e-mail, or by simply swapping radios between different groups. After Hurricane Katrina in 2005, first responders in the Bay St. Louis and Waveland, Mississippi area were unable to communicate with each other for several days—and in some cases weeks—following the storm. Communication between first responders was first re-established not via traditional radio networks, but instead by deploying Internet Protocol-based technologies such as satellite uplinks, WiMAX point-to-point radio links, Wi-Fi clouds, and Voice over Internet Protocol (VoIP) telephones (Steckler 2009).

Disasters that occur in locations that lack existing robust communication networks, such as many third world countries, present a unique challenge to international and local first responders. Following the earthquake in Port-au-Prince, first responders were confronted with a country that had an inadequate indigenous response capability: There existed little communications infrastructure, no earthquake disaster preparedness measures, and a corrupt and mostly ineffective government that had few trained personnel capable of responding to the catastrophe. Adding to this challenging environment, the disaster resulted in massive causalities—approximately 222,570 by United Nations estimates—and the crippling or total ruination of seventy percent of structures within Port-au-Prince and the surrounding areas (United Nations Office for the Coordination of Humanitarian Affairs). Response to the disaster was further hampered by the destruction of the City's seaport and the international airport's air traffic control tower. For the hours and days immediately following the event the only way to move goods and materials into Port-au-Prince was via air transports using visual flight rules, or trucks dispatched from the Dominican Republic—a 4.5-hour trip with no traffic. Predictably, the disaster caused a traffic jam on roads leading to and from the Dominican Republic; drive times of 14 hours or more were reported to the author by first responders who had traveled from Santo Domingo to Port-au-Prince.

NGOs, foreign governments, and other organizations mounted a large and rapid response to the crisis, sending huge amounts of relief supplies, first responders, and logistical support. Billions of dollars were pledged from nations, groups of nations, NGOs, individuals, and other organizations. Countless tons of relief supplies were flown, trucked, and shipped into Port-au-Prince. United States President Barack Obama declared that the people of Haiti "will not be forsaken; you will not be forgotten," and set into motion one of the largest disaster response operations in United States history (Obama 2010).

The United Nations established a large logistics base ("UN log base") at the Port-au-Prince airport, which became a central meeting place and communication forum for first responders of all stripes. Organizations as varied as World Vision, the International Committee of the Red Cross (ICRC), the government of Morocco, United States military officers, and representatives from the government of Haiti, and UN peacekeepers from a variety of countries all worked within the same conglomeration of tents, mobile trailers, sun shelters, and open air courtyards. Attempts were made to coordinate between organizations with varied levels of success. The UN cluster system meetings, where organizations with similar relief goals met together in an attempt to synchronize efforts, became the hub of cross-organizational coordination and collaboration. Organized by interest area, such as Health, Food, Communications, the cluster meetings presented an environment where issues could be discussed, and solutions proposed.

The meetings also represented the best opportunity for first responders to get in contact with each other, as it could be assumed that certain organizations would likely attend certain meetings. This method often proved imperfect since not all organizations were always present at each meeting. Daily participation by each organization is difficult due to travel distances, transportation logistics, staffing shortages, and a dearth of available time. If a responder was searching for a specific organization not represented at the cluster meeting, and the next meeting was too far in the future, the next best method for getting into contact was to conduct a manual search by walking around the UN log base. The author observed first responders who spent hours walking around inquiring about the whereabouts of a specific person or an organization. That time lost represents a large amount of valuable man hours that could be better spent working any number of other response-related tasks. This task was made still more challenging by the occasional individual who did not seem “forward leaning,” and was uninterested in helping.

Within the Haitian earthquake response there existed a wide variation in the willingness of each organization to work with other organizations. The author observed productive collaborations between several organizations, such as communications-focused NGOs providing assistance to those without communications capabilities, and a technical exchange between the World Food Program and Télécoms Sans Frontières; the author also observed organizations that refused to collaborate with certain other organizations, such as Médecins Sans Frontières’ refusal to work with the militaries of any country. Unfortunately, these observations are consistent with the observations of many others during this and prior disasters. Lack of coordination is the norm, rather than the exception (*The Economist* 2010, 35–36; Comfort and Kapucu 2006, 309–327; Garnett and Moore 2010, 28–29; Keen et al. 2010, 2–12; Lindsay 2010, 18–22; Piotrowski 2010, 107–112; Parker 2003; McEntire 1999, 351–361).

Although face-to-face meetings were often the preferred method of communication, one of the more reliable means of getting in touch within the UN log base, and to workers outside the log base walls, was e-mail. The World Food Program, a UN-run NGO that focuses primarily on food distribution, set up an open Wi-Fi network near the center of the UN log base. This resulted in a kind of outdoor "Internet café" where first responders gathered. This congregation represented not only an opportunity to communicate electronically with others, it also created an opportunity for first responders to "bump into" each other and socialize their needs, ideas, and observations. Like the proverbial watering hole as a meeting place for animals on the savannah, the availability of a Wi-Fi cloud created a valuable opportunity to assemble, communicate, collaborate, and improve the exchange of needs assessment data that is critical to efficient disaster response.

III. VIRTUAL SPACE

The aforementioned methods of communication and information portals combined form the status quo for a disaster relief virtual space. This virtual space is occupied by first responders, volunteer and paid programmers, victims, the families and friends of victims, government agencies, and non-governmental agencies. Their interactions are enabled by the global Internet and the spaces provided by websites, information portals, visualization tools (such as mapping and GIS), blogs, social networks, and sites that enable messaging over web and SMS such as Twitter and GroupMe. Within the virtual commons, the people involved with and affected by a disaster interact, gather and process information, and ultimately attempt to improve the situation. As opposed to a virtual space-less environment, such as that which existed before the advent of widespread information technologies, virtual communication and collaboration results in greater exchange of information at a more rapid pace (Allen 1977; Summer 2010, 55–68).

Large-scale data exchange with responders on the ground and others around the world was achieved primarily through a tangle of "disaster relief portals," each with its own database, user interface, and user accounts. The end user requirements for entry to each site varied depending upon the organization. For example, the UN Virtual OSOCC (On-Site Operations Coordination Center) required users to register and be approved by a site administrator before access is granted; the US Department of Defense–run All Partners Access Network (APAN) required a similar approval process after filling out an arduous account application. Over the course of a multipage web-based application process, each user was required to provide extensive contact information, proof of where the user worked, and an extremely long and complex password. There were few cases of data exchange between disaster relief portals, a fact which created several "stove pipes" where data was housed and not shared horizontally.

Any increase in communication and collaboration is desirable; as noted in the prior chapter, the current state of disaster response lacks the coordination that could result in more effective operations. The system proposed creates a novel virtual space, utilizing extant software and online communities to create a “mashup” of effective systems that result in a more efficient disaster response enterprise. The system also leverages very low bandwidth, widely available, and familiar technologies that use standard mobile phone networks to provide access to the virtual space from any nearby location. By combining the virtual space, a path to access the virtual space, and a physical space that allows for face-to-face collaboration (discussed further in the next chapter), the proposed solution creates a system that increases communication via three of the most vital areas: the physical, virtual, and social worlds.

IV. PHYSICAL SPACE

In disaster response first responders often operate primarily within their own operating space; that is to say, the majority of their energy is focused inward and toward their organization’s primary goals, which are often dictated by donors. First responders disperse across a relatively large geographical area, seeking out those in need to dispense aid. This geographical dispersion and inward organizational focus results in a situation where, in a connectivity-starved environment, detachments of first responders are effectively isolated from all others after they leave a base of operations. This was often true in Haiti, despite the fact that the indigenous cellular network remained relatively stable and usable throughout the disaster response. First responders either did not have the financial resources to purchase local mobile phones and service from local network providers, did not wish to rely on local providers, had difficulty coordinating the logistics to procure mobile phones and distribute them, or did not know that the network was usable. Given this total disconnection, it was often the case that aid workers and first responders would depart their logistical base of operations in the morning and not be in contact again until they returned in the evening.

NGOs positioned at static locations, such as hospitals, fared little better. The author visited several medical facilities and found identical conditions at each. *L’Hôpital de la Communauté Haïtienne*, or Haitian Community Hospital (HCH), located in the Petionville district of Port-au-Prince, had a residential-grade satellite Internet connection that worked intermittently, allowing small bursts of data, such as a few e-mails, to be sent during short windows of connectivity. This allowed the hospital to send requests to the outside world, however since most in-country first responders did not have consistent access to e-mail—and few knew how to get into contact with first responders from specific organizations anyway—even the connectivity they did enjoy had limited utility.

Unreliable or a complete lack of communication was the case not only with NGOs, but also with organizations that are typically considered to be much more capable in deployed scenarios, such as the United States military. On 22 January 2010, the author was deployed from the USNS Comfort to field hospital Terminal Varreux to help facilitate communication between field hospital personnel and the Comfort. The facility was manned by approximately 30 medical professionals—doctors, nurses, respiratory specialists—deployed by the United States Department of Health and Human Services, as well as medical officers from the United States Navy. Upon arrival it was clear that although the facility had its own VHF radio capability and a person dedicated to communications, their radios were not compatible with the radios used by the Comfort, and communication with the ship was accomplished via an intermediary stationed elsewhere in Port-au-Prince. In practice, this method of communication was unreliable. Variable contact with the ship meant medevacs of victims, resupply requests, and other vital messages were not received by the ship. Terminal Varreux, geographically isolated and staffed by United States Government and military personnel, was little better off than the NGOs who deployed without any communication capability.

V. THE SYSTEM

Given that organizations have their own specialties and strengths, and collaboration between groups would result in more positive outcomes in disaster relief, it is clear that it would be beneficial to facilitate intergroup communication and cooperation, in both the physical and virtual worlds. By providing a space where each organization could always be found, in both the physical and virtual worlds, the difficult communication situation could be greatly improved. This physical space could be a large tent, set up by a neutral party such as the United Nations, with tables set up for representatives from each organization—NGOs, militaries, government agencies—all included and encouraged to participate. The space would provide wired open Internet access—not a proprietary network such as the United States Department of Defense SIPRNet, NIPRNet, or any similarly restricted network—as well as Wi-Fi network connections. Internet access could be provided by the World Food Program, the United States Department of Defense Joint Communication Support Element (JCSE), or whoever is capable of providing such connectivity. Similar to the Internet Café set up by the World Food Program at the UN log base in Port-au-Prince, it is certain that in a connectivity-starved environment that people will gravitate toward the places where connectivity is available, such as the proposed tent. This lure then facilitates contact between organizations that would not have otherwise communicated with each other.

This proposed combination of a physical and virtual space also creates a dynamic where first responders may leave the physical space of the tent, but they are still members of the virtual space and the community inherent therein. These two spaces amount to a new first responder ecosystem where it is possible to work more closely together, even if physical proximity is not maintained.

A. STRUCTURE OF THE SYSTEM

The proposed system is comprised of four primary components: The mobile phone network, mobile phones, the software infrastructure required to support the system, and EOC tent. (See Figure 2.) The cell phones—basic units with GPS, long-lasting batteries, and only texting capability—are backed by either the indigenous mobile phone network or a network provided by a rapidly deployable means, such as a Cellular-On-Wheels System (COWS) or an Unmanned Aerial Vehicle (UAV) with the appropriate antennae and optional backhaul connection to a larger mobile network. Once turned on, the phones themselves ask the user to select which organization they are from, e.g., “World Food Program,” “Save the Children,” “UN-OCHA,” “US Military,” etc., and for a user identifier, e.g., “John Doe,” or “Food Distribution Detachment 1.”

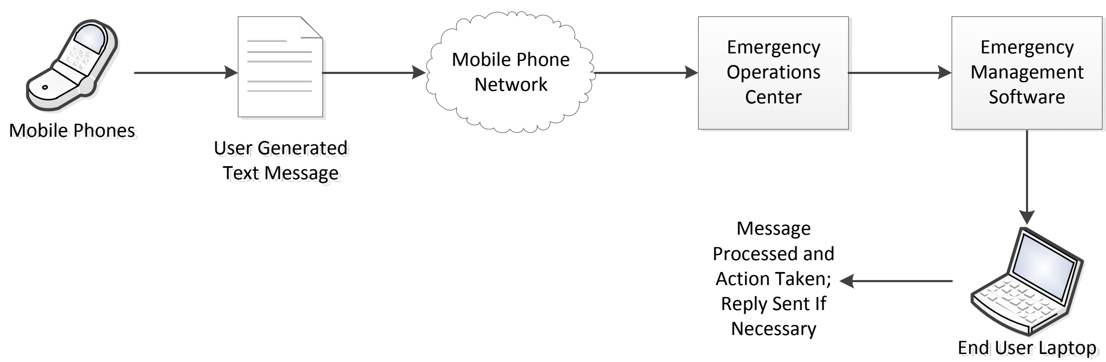

Figure 2. System Components and Path of Messages.

When a text message is sent from the phone, the message is geocoded to the users location and sent to the central EOC tent. The message is then routed to a laptop inside the tent, where a representative from that user’s organization stands watch around the clock for the duration of the disaster. The message is displayed on a map along with the user’s name and the time the message was sent. The representative then has the option to respond directly to that user via text, forward the message to someone else in the network, or act upon the content of the message. For example, if the message said, “Food distribution becoming violent, need force protection,” the representative then has an easy way to address the issue: Forward the geocoded message to a military representative who is also physically sitting nearby in the same tent. If desired, the representative could walk over to the military representative to follow up on the contents of the message. This creates a two novel spaces—one virtual and one physical—which enable first responders to rapidly communicate within their organization and with any other participating organization, either via the physical or the virtual spaces.

B. MOBILE NETWORK

Significant infrastructure is usually required for any wireless network that blankets an area with widely available coverage. For this reason, and given the indiscriminate destruction that accompany disasters, it would seem inadvisable to attempt any sort of network based on the widespread availability of a wireless network. However, over the last decade it has been shown that modern mobile phone networks are remarkably robust and capable of withstanding significant damage. The indigenous mobile phone network in Port-au-Prince was never fully inoperable, and victims were able to send text messages within hours of the 7.0 earthquake (Meier and Munro 2010, 91–103). All of the mobile phone network providers in Christchurch, New Zealand reported that their networks remained partially or fully operational following the 6.3 magnitude earthquake on 22 February 2011 (Anonymous 2011). Thus, if available, the system could use indigenous mobile phone networks as a backhaul to the EOC tent.

If the indigenous network is no longer operable, there are a number of options available to create a hastily formed mobile phone network, including Cellular On Wheels Systems (COWS), Unmanned Aerial Vehicle-mounted (UAV) systems, as well as the option to leverage existing cell sites for new and repaired equipment. (See Figure 3.)

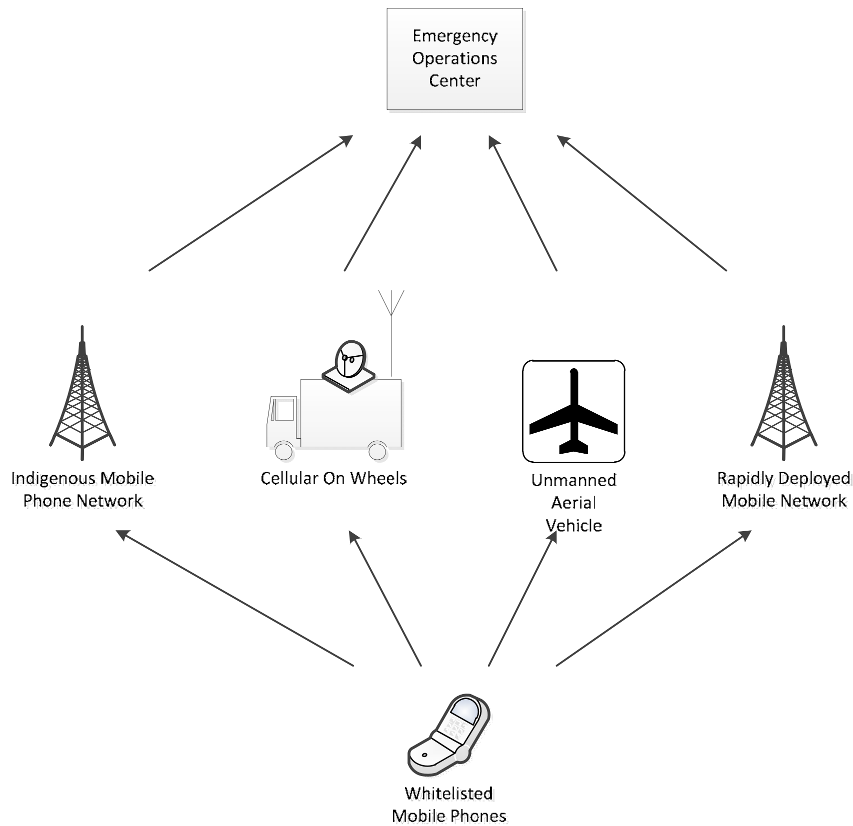

Figure 3. Mobile Phone Network Options.

COWS provide mobile phone antennae, generator power, and backhaul connections on a rapidly deployable platform, such as a trailer or a self-propelled truck. Those systems can provide service equivalent to standard static cellular tower sites, enabling hundreds or thousands of users over several square miles to connect to the mobile phone network (Tipper, n.d.). Such units could be flown into the area of operation and deployed throughout the affected area, using any surviving terrestrial wiring for backhaul, or satellite connections back to the greater telephone network (and therefore the Internet at large).

UAVs have the capacity to carry a variety of payloads and to loiter over any area for an extended period of time, and those capabilities combined can be leveraged to transform a UAV into a kind of cell tower in the sky, where the UAV is equipped with cellular electronics and antennae on its underbelly and wings, as well as different antennae to create a wireless backhaul connection either to a terrestrial base station or a satellite. UAV-based cellular networks have two primary advantages: (1) as opposed to setting up a terrestrial network of cellular phone towers, UAVs can be deployed relatively rapidly, and (2) the coverage area afforded by an airborne platform is far greater than that of terrestrial antennae. Assuming a system with a five watt amplifier and standard CDMA equipment, a UAV flown at 5,000 feet could cover an approximately 20-mile area in diameter (Varga 2009). A number of smaller UAVs could be networked together in a mesh, along with a mesh node on the ground, providing a self-contained mobile network that would not require a backhaul connection to the telephone network at large.

There is also the possibility for the indigenous terrestrial infrastructure to be repaired. Another option is to leverage the physical infrastructure, such as cellular towers, power wiring, etc., to either build or rebuild the terrestrial network. This solution may be preferable in situations where damage is limited and there are sufficient personnel with the requisite knowledge to build the infrastructure, since building more permanent locations means implementing a solution that will remain after the disaster response phase is complete. The Swedish company Ericsson has a unit of their company specifically dedicated to working in austere conditions and disaster response scenarios (Ericsson). Their expertise, and other companies like theirs, can be used to rebuild critical infrastructure and get an operable network back into operation.

It is also possible to develop and deploy a ground-based GSM system with minimal infrastructure by utilizing standard antennae, amplifiers and base station units, basic computers (laptops, desktops, or servers), and open source software. OpenBTS is a software product maintained by the open source software community that is capable of advanced management of a GSM mobile phone network. The software, along with easily obtained commercial off-the-self parts, has been deployed in challenging terrain and austere environments, most notably serving thousands of handsets in extremely harsh desert conditions at the annual Burning Man festival in the Black Rock Desert in Nevada. The OpenBTS system also powers the GSM network for the island of Niue in the Pacific, serving a population of 30,000.

In order to avoid network congestion, the mobile network should have the capability to “whitelist” certain phones so that only first responders can connect and send and receive messages. System operators should determine an easy-to-remember SMS shortcode to which all messages will be sent. It is important to select a shortcode that is also available on indigenous networks, so that if the user wishes to connect to the indigenous network instead of the first responder-only network, his or her messages to and from the proposed system will still be routed correctly.

A. MOBILE PHONES

End users of the rapidly deployed mobile network, or the rebuilt terrestrial network, require mobile phones to access the services of the proposed system. There are two possibilities for getting mobile phones into the hands of first responders: Either they bring their own mobile phones, or mobile phones are provided to them. Since the system is entirely based upon SMS, GPS, and a standard mobile phone network technology, such as GSM, only a very simple phone would be required. A unit with a QWERTY keyboard, low power consumption, a large battery, and GPS capabilities would be ideal. There are numerous existing phones available on the consumer market that meet those qualifications. It is also likely that an organization that already produces mobile phones and has a pre-existing interest in disaster response, such as Ericsson, would have an interest in providing a solution to the phone problem. If an industry partner cannot be found then the phones could be sourced and purchased in bulk by one of the larger NGOs that has an interest in disaster communications, such as the World Food Program.

It is also likely that some first responders will bring their own mobile phones and will wish to use them to participate in the proposed system. Provided the underlying wireless technology used in their mobile phone is compatible with the network in use in the disaster area, this can be accommodated by gathering their phone’s identifying information, such as International Mobile Equipment Identifier (IMEI), Subscriber Identity Module (SIM) card information, etc., and whitelisting their phone on the network. The user’s identifying information, such as first and last name and organization, should be associated with the user’s phone information, so that when messages are received from that user the messages can be routed appropriately. From the user’s perspective, he need only text his messages to the appropriate shortcode using their mobile phone’s built-in SMS application, and their organization’s representative in the tent will be able to reply.

If geocoding is desired, and a terrestrial network is used, the proposed system could locate the user with low precision by detecting which mobile network tower he or she is associated. This approach would not be practical if the proposed system utilized a UAV for network service, since the coverage area provided by the UAV would be too large to make location information useful and easily calculated. In that case, the user has two options: Manually input his latitude and longitude coordinates into the text message, or state where he is relative to landmarks, and the organization’s representative could then manually geolocate the user.

It is also possible that a separate application could be programmed to run on first responder’s phones that would automatically add geolocation information to each text message. This approach is likely not feasible since it requires software developers to (1) build and maintain specialized software, and (2) build versions for each of the phone platforms that first responders may wish to use. Loading the software to the phones would also present a problem, as most mobile phone operating systems rely on “app stores” that require connections to the Internet and all applications to be preapproved for inclusion by the company in charge of the store.

The geolocation issue, along with the desire to have low-power phones that have high-capacity batteries, mean that distributing low-cost mobile phones is likely the best solution for the proposed system. The distribution of phones also means that first responders would not need to concern themselves with bringing their own phones and cope with a wide variety of chargers and power requirements.

B. SOFTWARE INFRASTRUCTURE

All of the components of the proposed system are intended to be chosen from commercial off-the shelf (COTS) products, including the software infrastructure. The system will require three primary components: Operating systems, SMS gateway software, and user-facing visualization and messaging software. (See Figure 4.)

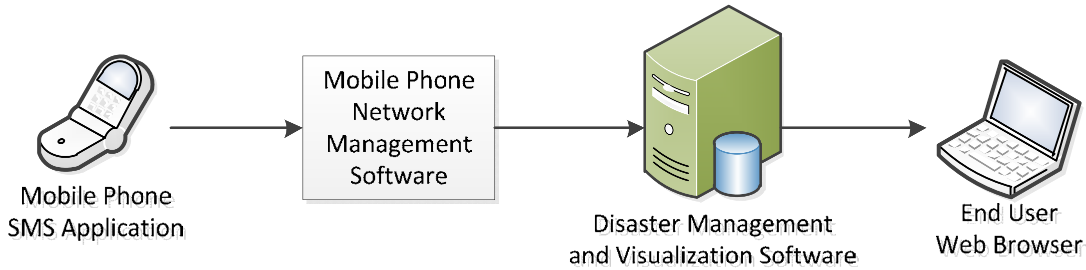

Figure 4. Software Infrastructure Components.

Servers, located in the EOC tent to lessen the bandwidth requirements on any backhaul links to the Internet, should run commercially-available and widely supported operating systems such as Microsoft Windows or Linux. This not only ensures low cost, but also the possibility that someone will know how to repair the operating system or applications if there are any failures while the system is deployed in the field. The SMS gateway software installed on the servers should be capable of sending and receiving thousands of messages per day with very high reliability (beyond “five nines” of reliability). Compatibility and performance with carrier text messaging systems should also be taken into consideration since it is probable the proposed system will need to interoperate with indigenous text messaging systems.

The user-facing software shall consist of text messaging software, mapping and visualization tools, and standard web tools. The user laptops shall run Microsoft Windows, Mac OS X, or an easy-to-use version of Linux with an interface that will be familiar enough to most users so that they will be able to operate the laptop with minimal difficulty. The mapping and visualization tools shall allow the user to read incoming messages, see those messages plotted on a map, and easily respond to the message, or forward the message to another user or organizational representative. Such software already exists. For example, Ushahidi is an open source crowdsourcing and mapping application specifically designed to visualize SMS information taken from large groups of users. Other products could be used; the most important factors in choosing the visualization software are: Reliability, ease of use for users who are unfamiliar with the software, and ability to incorporate new map data from a variety of sources on the fly (i.e., terrain data, imagery from military UAVs, user-input notes from OpenStreet Map).

Both the server and the user software shall be maintained as disk images that can be rapidly replicated onto a wide variety of consumer hardware. System performance requirements should be kept at a minimum so as to ensure all computers that are brought to the disaster will be capable of effectively running all software packages. Server and user software shall also be available as individual package files on a single disc or in a repository location on the Internet.

The server and user software packages will need to be created and maintained by an organization or a group of users. An NGO with an interest in IT could be asked to maintain software images. The task could also be given to a group in the tech community. Many successful humanitarian software projects exist as completely volunteer-staffed efforts, and there is no reason why these software packages could not be supported by a group of self-organized and dedicated tech-savvy programmers.

C. EMERGENCY OPERATIONS CENTER TENT

All of the text messages sent by first responders in the field will be sent to an EOC tent or other structure located at a central meeting place, optimally where the most first responders have decided to congregate. The structure itself could be provided by a military organization, an NGO, or the UN. The lighted tent will have tables set up with laptops, power outlets, WiFi, and wired networking. Each of the laptops and associated desk positions will be available for any organization that wishes to post a representative inside the tent twenty-four hours a day, seven days a week. Part of the strength of the system is this guarantee that representatives from each organization are physically present inside the tent, thus there should be incentives or disincentives designed to keep the tent staffed at all times. For example, the system could be designed such that if the representative leaves the tent for an extended period, perhaps more than half an hour, that representative's access to the system will be temporarily suspended, and the first responder's from that organization will receive a message that states their representative has left his or her post. The representative will then need to go to the agency in charge of the tent and the network to explain their absence. It will then be up to the agency to decide whether to reinstate that organization's access to the network. If access is granted once again, first responders in the field will receive a message that says access has been restored. Such heavy-handed policies may be required to encourage first responders and their organizations to keep a representative present in the tent at all times—presence that is vital to effective cooperation and collaboration. (See Figure 5.)

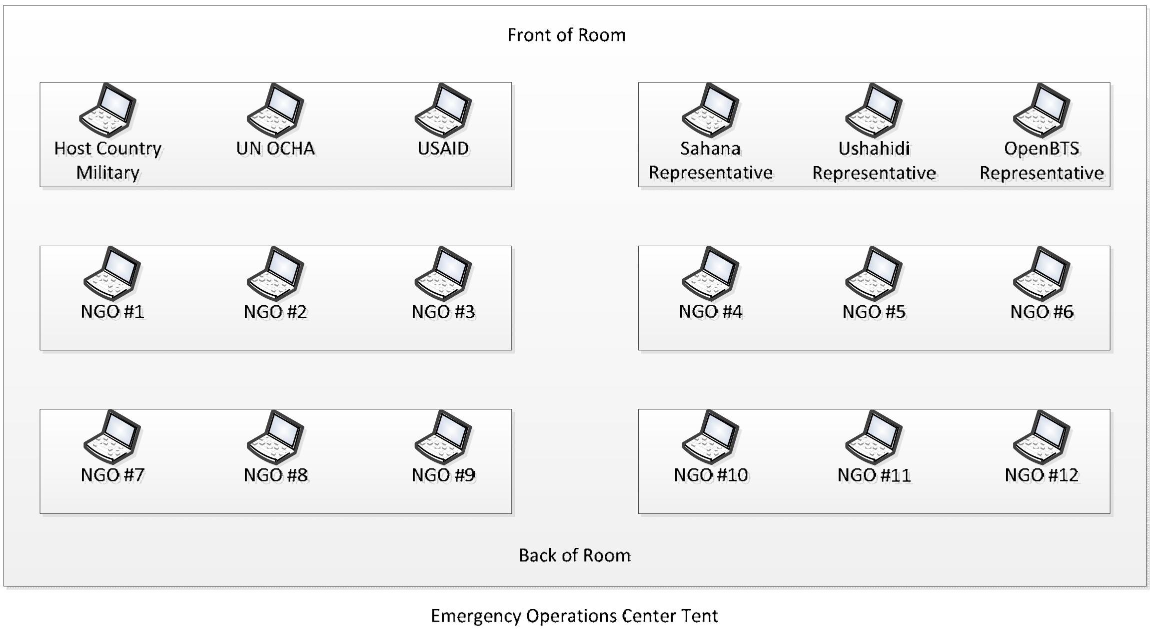

Figure 5. Example Emergency Operations Center Layout.

If implemented well, the EOC tent could become an excellent supplement, or even replacement, for the cluster meeting system. Since information would be flowing between organizations at all times, it would become less important to hold daily meetings.

The value of the face-to-face interaction afforded by the EOC tent should not be understated. Trust between individuals and between groups is earned over time, and that trust can be built much more quickly when those individuals are interacting face-to-face.

The availability of a free and open WiFi network with access to the Internet will also be a significant draw for first responders, similar to what was observed with the WFP's Internet café at the UN log base in Port-au-Prince.

VI. ENTERPRISE ARCHITECTURE

The disaster response business enterprise in Haiti existed as a multi-headed organization led partially by the United States and partially by the United Nations. NGOs looked to both organizations for help in areas such as transportation, force protection, and supplies, although some NGOs attempted to operate independently. There were seemingly no rules governing who was in charge and who could enable or prevent others from pursuing a given goal. In this way, there was no official hierarchy directing the activities of each—aside from the generally accepted standards of human conduct—however many organizations relied upon one another for logistics support, supplies, etc. In this enterprise, materials, logistical systems, and even aid workers were often shared on an ad-hoc basis, but there was no formal system in place to coordinate those efforts. Connections were made in a serendipitous manner, and tasks were identified and pursued based on those connections. For example, after observing a medical cluster group meeting at the UN Log Base, the author made contact with a pediatrician who ran an NGO dedicated to serving children in need of medical care. The physician noted the lack of a system that would allow first responders to know where hospitals and medical facilities were located, which facilities had which capabilities and had available beds. The author identified the needed features within Sahana, an open source web-based disaster response management software tool, and sent suggestions for changes to the programmers of Sahana based on feedback from the physician. The existence of that feature of Sahana was then socialized at the next medical cluster group meeting. By meeting one another face-to-face, identifying a problem, and pursuing known resources, a solution to a problem was found and implemented. Each participant in this ad-hoc association provided their own expertise, and a positive outcome resulted. This is illustrative of what can happen when disparate groups work together as an enterprise within the disaster response community. (See Figure 6.)

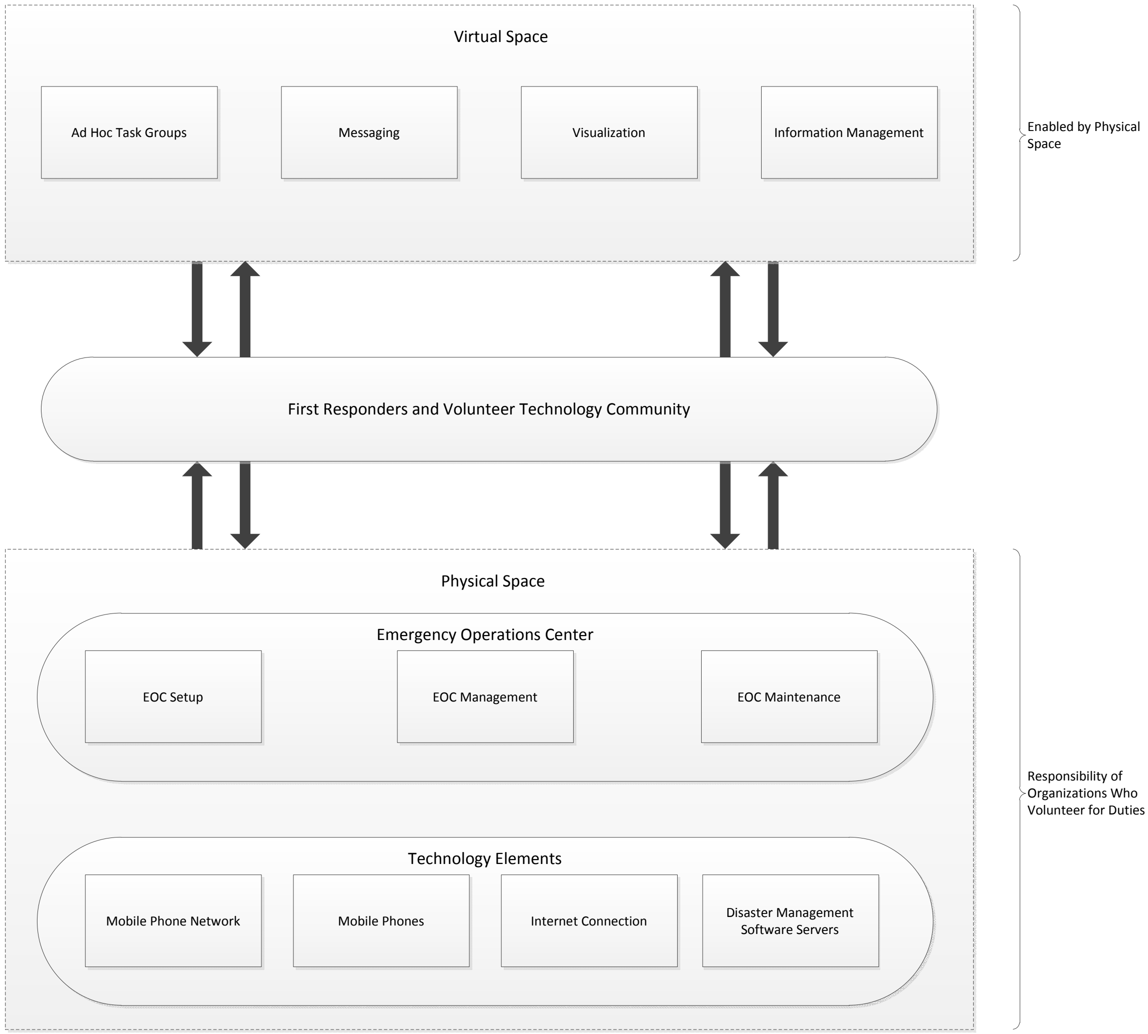

Figure 6. System Enterprise Architecture.

One of the keys to this interaction was the physical proximity of the willing actors. The creation of the EOC tent, the availability of free and open Internet access, the supply of free and operable mobile phones (and the accompanying requirement that every participating organization be present in the tent), are all intended to encourage ad-hoc interactions on a massive scale. Prior studies have noted in volumes that physical proximity increases productivity, efficiency, and interaction between disparate groups. Teasley et al. found that software development groups who worked together in the same room doubled productivity, and working more than thirty meters apart had the same effect on productivity as working remotely (Teasley et al. 2000). United States Army

Lieutenant General Keen, commander of Joint Task Force-Haiti, noted that being in the same room with first responders from Brazil, the United Nations, and other nations in the hours and days following the earthquake in Haiti was instrumental in rapidly formulating a disaster response plan (Keen et al. 2010, 2–12). It has also been shown that organizations that use electronic forms of messaging are far more productive at the same tasks as those organizations that do not use any sort of electronic messaging (Finholt, Sproull, and Kiesler 1990, 291–325). All of these studies were conducted in environments where stable communication networks were available. It is almost a certainty that similar results, if not better results, would be obtained if comparable studies were conducted within the communication-starved environment of a disaster area. Likewise, it seems a certainty that if organizations were physically located proximally to each other, and even those who were not always proximate knew where they could find representatives of another organization if they needed to, great gains in productivity would result. The hours it takes for one person to look for another specific person, or simply any representative of another organization, would be saved. Such improvement in lead time directly affects the total time required to deliver relief.

However, the ability and desire of each organization to work together with another varied widely. Cultural boundaries, differences in opinion, and other factors often result in strained relationships or even complete non-communication between groups. This inability or even stark refusal to work across organizations is highly unfortunate given that each organization has its strengths and its weaknesses, and combining efforts has the potential to result in a whole greater than the sum of its parts (Comfort and Kapucu 2006, 309–327).

The enterprise architecture as it existed in Haiti need not change much to support this proposed system. As mentioned before, an organization, likely the UN, would need to be responsible for setting up the EOC tent and enforcing the few basic rules, and another organization, also likely the UN, would need to be responsible for providing the mobile network (if the indigenous network is not functional), the mobile phones, and a backhaul Internet connection. Due to proximity, ad-hoc groups would form within the EOC tent, and those ad-hoc groups would achieve tasks that likely would have been much more difficult to coordinate, or simply impossible to coordinate, without the physical and virtual spaces created by the proposed system. Instituting more business architecture beyond that, such as requiring NGOs to report to the UN for permission for individual tasks, would cause backlash among independent-minded NGOs and would likely be counter-productive.

Indeed, the hope is that by creating an enterprise where all first responders interact and work on the same problem within the same virtual and physical space, that a kind of heedful enterprise would be created, one where each participant is more aware of what the other participants in the group are doing, and can therefore anticipate the needs of others in order to get more done. Such dynamics have been noted in several operational circumstances, and there does not exist any reason why that a similar level of understanding could not be attained through the proposed system (Weick and Roberts 1993, 357–381).

VII. DISCOVERY AND ALLOCATION OF SYSTEM

The proposed combination of mobile phones, mobile network, disaster management software, and EOC space, along with first responders from a wide variety of organizations, create a powerful combination of virtual and physical spaces where all components operating in concert create a whole greater than the sum of its parts. However, if first responders and organizations are unaware of or otherwise unable to find the system—or the system is simply unavailable—the value decreases as each person or organization does not participate. Thus it is important to identify methods by which first responders will discover the existence of the proposed system, both before a disaster occurs and during the response to an event. There are a variety of methods that could be employed to encourage discovery of the platform, including pre-disaster socialization of the system, prominent positioning of the system at key organizational points of a disaster area, and "viral" methods of discovery.

There is a vibrant and active community of volunteer technology experts who run various mailing lists, blogs, information portals, and other resources tailored toward the ultimate goal of alleviating the suffering of disaster victims. The existence and utility of the proposed system could be socialized within those groups, with volunteers encouraged to write about the system on various media, and to pass on the word about the system to first responders they know. Potential participating organizations could be asked to make a non-binding commitment to use the system at the next disaster where it has been successfully deployed. Provided they are cheap enough, phones could potentially be sent to organizations before a disaster occurs. (This approach carries with it a risk that organizations that do not have significant lift capacity could leave the phones behind in favor of other materials they deem to be more important.) The system could be presented to the leadership of various organizations before a disaster, and those leaders could make it the policy of their organization to use the system in the event of deployment to a disaster.

The existence of the system should be promoted at areas where first responders gather within the disaster area itself. Whenever the United Nations deploys to a disaster they set up an On-Site Operations Coordination Center (OSOCC) tent where first responders “check-in” to a disaster and announce their presence and the capabilities they have brought. The OSOCC has three stated objectives:

1. *To be a link between international responders and the Government of the affected country.*
2. *To provide a system for coordinating and facilitating the activities of international relief efforts at a disaster site, notably following an earthquake, where the coordination of many international USAR teams is critical to ensure optimal rescue efforts.*
3. *To provide a platform for cooperation, coordination and information management among international humanitarian agencies* (UN OCHA).

Promotion of the proposed system is clearly consistent with objectives two and three. As first responders check in, UN staff should suggest the system as a method to keep group members in constant communication with each other, as well as the first responder community at large.

UN cluster meetings also present a unique opportunity to socialize the existence of the system. At the beginning of each meeting an announcement could be made that states that the system is available to all first responders for no charge, and that the system represents a unique opportunity.

Perhaps the most compelling method for discovery of the system is user-to-user socialization. First responders who are in the field using the system will inevitably come into contact with other first responders who are not participants in the system, and when the non-participants see others text messaging successfully, or participating first responders suggest that they connect via the system, they will likely ask which network the user is using, where they procured the phone, etc. Provided that non-participant sees value in the system as described, they will likely attempt to participate thereafter. This method of discovery represents a type of viral discovery, where the user base could potentially grow exponentially as more and more users discover the system.

The system should be allocated with a series of rules and priorities. To prevent network congestion and overcrowding the network, only first responders should be allowed to access the network. In addition, larger and established organizations such as the World Food Program, Save the Children, World Vision, local government, etc., should be given access priority so as to ensure that the larger players within the disaster area participate in the physical and the virtual network. Consideration should be given to the idea that some organizations have reserved positions within the tent so as to optimize the physical space within the tent.

While open to all users, the data network within the EOC tent will have the capability to perform quality of service and traffic shaping. This is to ensure that if users start to upload large volumes of data, such as video or audio clips, that those uploads can be throttled so that data from other users can still be transmitted in a timely manner.

These policies will be created and enforced by the organization elected to manage the network. Since a complete end-to-end understanding of the deployed technology is valuable, it may be preferable that the organization placed in charge of the network be the same organization that has agreed to provide the mobile phones and mobile phone network.

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VIII. APPLICATION SCENARIOS

The proposed system should be deployed in any disaster scenario where communications are degraded and a heterogeneous group of NGOs, government organizations, and other organizations respond. The number of situations where the system is needed within disaster areas is virtually limitless; from coordinating food distributions to requesting force protection to reporting locations that require proper body removal to disease outbreak reports, the system would be invaluable to all first responders. The latter application, disease tracking, was a capability that was especially needed by medical professionals in Haiti, and it was only partially solved many weeks into the disaster after Internet connections became more available and health workers were able to participate in online discussion groups (MMWR 2010, 1320–1324).

The system could be used as a type of universal information service, similar to the 611 systems implemented in many American cities. First responders could send messages with general questions, such as, “Where can I find a medevac location,” or “Where is the nearest hospital with an x-ray machine?” Those questions can be answered either by their organization’s representative in the EOC tent, or the message could be forwarded to the appropriate person who has knowledge of an acceptable answer.

It is also conceivable that the system could be programmed to request data from field workers at regular intervals. Such functionality would be useful in gathering daily updates on medical facility capabilities, capacity, sickness and mortality rates, and other similar data points. A text could be sent to field hospitals every morning requesting that information and, once gathered, that same information could be posted to central information repositories, such as Sahana, and further distributed either via web or via the proposed system.

Because the system itself could be deployed with a relatively small amount of hardware, the decision of when to deploy the network and phones need not necessarily be made before the responsible organization deploys to the disaster area. If for example, the World Food Program decided to be responsible for distributing phones and maintaining the mobile network, they could transport the system to the disaster area, perform a site survey, and if conditions warrant, distribute phones and turn on the network. There is little downside to deploying the proposed network, provided users are transitioned off of the temporary network and onto a more permanent solution in an orderly fashion.

Although the proposed system is designed to be used in international and domestic disaster response scenarios, there are a variety of other situations where the system could be of use. The system could be deployed in large Internally Displaced Persons (IDP) camps in order to facilitate communication between residents and relief workers, and to rapidly distribute camp announcements and information. It could also be linked to the worldwide telephone network so that residents could text with relatives and friends across the globe.

It is also conceivable that the system could be commercialized and distributed to workers in a geographically concentrated area, such as large construction sites. The advantage being that subcontractors and workers would have to identify themselves when they turned on the phones, and therefore an easy-to-understand master list of contacts could be maintained by the general contractor. It would be relatively easy to contact those subcontractors thereafter via the master list.

IX. CONCLUSION

The technology to improve communication, collaboration, and cooperation in disaster response already exists. This paper proposes fusing those technologies—low cost mobile phones, lightweight and rapidly deployable mobile phone network, and disaster response management software—along with an EOC tent and an organizational framework in which organizations can collaborate. Every one of the components in this system are reliable, procurable, and familiar to first responders. Aside from those items, all that is required is that first responder organizations have the desire and wherewithal to agree to implement it and communicate.

The system could be built collaboratively, with many different organizations contributing different parts of the system. For example, one organization could be in charge of setting up and running the EOC tent, another in charge of maintaining the disaster management software, another in charge of providing mobile phones. Such development could be created quickly in collaborative experimentation environments in both the physical and virtual worlds.

The system outlined above proposes a solution to two seemingly intractable problems: How to physically communicate within a disaster area, and how to increase cross-organization cooperation and collaboration. By implementing the proposed system, the disaster response community has an opportunity to potentially change for the better the way communications are handled in large scale disasters—and by doing so, potentially save countless lives.

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